The Method of Calculating Average Skidding Distance

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ABSTRACT By analyzing the existing average skidding distance formulae and the shape of the landing area, the authors put forward that the average skidding distance is the shortest when the ratio of length and width is 1, and the landing collection area is in proportion to of average geometrical skidding distance. The new models of calculating average distance are presented.

Key words: Average distance, Calculation method, Loggingarea

INTRODUCTION

Average skidding distance is a main factor that should be considerated when we calculate the formula of reasonable forest road network, and it is an important factor to evaluate the allocation quality of road network.

The formula (1) is given by prof. Ywakawa, a Japanese.

$$E = (l_a + l_b)/2 \tag{1}$$

Where $l_a = \sqrt{\left(\frac{2}{3}a\right)^2 + \left(\frac{1}{3}b\right)^2}$, $l_b = \sqrt{\left(\frac{2}{3}b\right)^2 + \left(\frac{1}{3}a\right)^2}$

The Fig.1 shows a rectangular logging area where the landing locates at point O. Point Q stands for center. a is the length of long side, and b of short side. Prof. Ywakawa divided the rectangle into two triangles and found out each barycenterms A, B, then calculated the distance from A or B to landing center, and gained average skidding distance E.

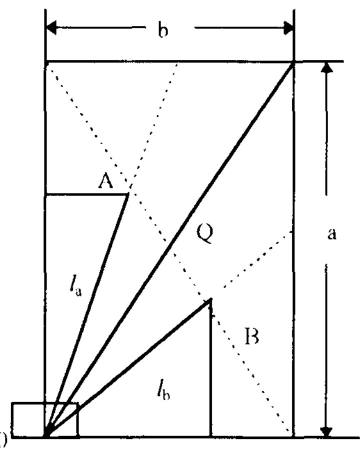

Fig.1. Logging area

The formula (2) was given by Prof. Okawahara.

$$E = \mu(a+b)/2 \tag{2}$$

Where μ is a coefficient which was changed according to the ratio of length and width.

Researchers in China used to regard the distance from center Q to landing center O as average skidding distance. It is important to solve that which method is more reasonable, how much is different about them, how these methods are conversed in the theory of road network.

CALCULATION

Prof. Okawahara put forward two hypotheses. One is: total skidding work(distance × skidding volume) equals to the power from one point on which all volume are concentrated to landing center, this distance is average skidding distance. The other is: the standing trees are uniform distribution. If a skidding road is allocated along rectangle diagonal, apparently the average skidding distance is $\frac{1}{2}\sqrt{a^2+b^2}$. If two skidding roads are allocated along two triangles center-lines, then the average skidding distance is $(l_a + l_b)/2$. But in fact, the skidding roads which are allocated in radial should depend on the tractor's mechanism and type to define the appropriate attraction area of every skidding road, and divide the logging area into a number of triangles (assume $2n$ of triangles), and then calculate the distance from each barycenterm to the landing center, thus:

$$E = \frac{1}{2n}\left(\sum_{k=1}^{n}\sqrt{\left(\frac{2}{3}b\right)^2 + \left(\frac{2k-1}{3n}a\right)^2} + \sum_{k=1}^{n}\sqrt{\left(\frac{2}{3}a\right)^2 + \left(\frac{2k-1}{3n}\right)^2}\right) \tag{3}$$

The results show: the average skidding distance changes little although n increases.

When $a:b=1:1$, i.e. it's a rectangle, and its changing results are listed in table 1

Table 1. The number of triangles and average skidding distance (a : b = 1 : 1)

Number of triangles	2	4	6	8	10		20
Average skidding distance	$0.7454a$	$0.760a$	$0.763a$	$0.764a$	$0.7644a$	....	$0.765a$
Relative error		1.96%	2.36%	2.50%	2.55%		2.63%

When $a:b=2:1$, results are listed in table 2.

Table 2. The number of triangles and average skidding distance (a : b = 2 : 1)

Number of triangles	2	4	6	8		20
Average skidding distance	0.579a	0.589a	0.592a	0.5922a	....	0.593a
Relative error		1.73%	2.25%	2.28%		2.42%

When $n\to\infty$, let $a : b = \tau:1$, then

$$E=\frac{1}{ab}\left[\int_0^{\operatorname{arctg}\tau}d\theta\int_0^{b\sec\theta}\rho^2d\rho+\int_0^{\operatorname{arctg}\frac{1}{\tau}}d\theta\int_0^{a\sec\theta}\rho^2d\rho\right]=$$

$$\frac{1}{ab}\left[\frac{1}{3}b^3\int_0^{\operatorname{arctg}\frac{1}{\tau}}\sec^3\theta d\theta+\frac{1}{3}a^3\int_0^{\operatorname{arctg}\frac{1}{\tau}}\sec^3\theta d\theta\right] \qquad (4)$$

$$=\frac{1}{ab}\left\{\begin{array}{l}\frac{1}{3}b^3\left[\frac{1}{4}\ln\frac{1+\sin\theta}{1-\sin\theta}+\frac{1}{2}\operatorname{tg}\theta\sec\theta\right]_0^{\operatorname{arctg}\tau}+\\ \frac{1}{3}a^3\left[\frac{1}{4}\ln\frac{1+\sin\theta}{1-\sin\theta}+\frac{1}{2}\operatorname{tg}\theta\sec\theta\right]_0^{\operatorname{arctg}\frac{1}{\tau}}\end{array}\right\}$$

When $a:b=1:1$, get $E=0.765a$

When $a:b=2:1$, get $E=0.593a$

When $a:b=10:1$, get $E=0.5064a$

E_1 is an average skidding distance from the rectangle center to the deck center, E_2 is an average skidding distance getting from the triangle centers. When $n\to\infty$, the difference between E_1 and E_2 can be got through making comparison.

Table 3. Average skidding distance and error

	1:1		2:1		10:1	
	distance	error	distance	error	distance	error
E_1	$0.707a$	7.58%	$0.559a$	5.73%	$0.5025a$	0.77%
E_2	$0.745a$	2.60%	$0.579a$	2.36%	$0.5037a$	0.54%
E_{max}	$0.765a$		$0.593a$		$0.5064a$	

The comparison results show that the method recommended by Prof. Ywakawa has lower error, relative error is not exceed by 2.6% even though compared with limit value, and the relative error become less accordingly with increasing the ratio of the length and width. The accuracy from Prof. Okawahara's method is decided by μ μ can be obtained according to the formula (2).

$$\mu=\frac{\sqrt{1+4\lambda^2}+\sqrt{\lambda^2+4}}{3(1+\lambda)} \qquad (5)$$

Where λ is the ratio of length and width in this rectangle

Let

$$\frac{\mu(a+b)}{2}=\frac{1}{2}\left(\sqrt{\left(\frac{1}{3}a\right)^2+\left(\frac{2}{3}b\right)^2}+\sqrt{\left(\frac{1}{3}b\right)^2+\left(\frac{2}{3}a\right)^2}\right) \qquad (6)$$

Both sides of the equation are divided by b, and let $a/b=\lambda$, then

$$\mu(H\lambda)=\sqrt{\left(\frac{1}{3}\lambda\right)^2+\left(\frac{2}{3}\right)^2}+\sqrt{\left(\frac{1}{3}\right)^2+\left(\frac{2}{3}\lambda\right)^2}$$

We get formula (5).

Let $\lambda=1/m$, get formula (7).

$$\mu=\frac{\sqrt{1+\left(\frac{4}{m}\right)^2}+\sqrt{\left(\frac{1}{m}\right)^2+4}}{3\left(1+\frac{1}{m}\right)}=\frac{\sqrt{1+4m^2}+\sqrt{m^2+4}}{3(1+m)} \qquad (7)$$

Prof. Okawahara pointed out that $\mu=0.8$ is appropriate, and this paper define the μ according to the different ratio of length and width.

CONCLUSION

Two conclusions can be obtained from these formulae of average distance:

1. Landing collection area is in proportion to square of average geometrical skidding distance :

Let $\frac{1}{2}\mu(a+b)=\frac{1}{2}\varphi\sqrt{a^2+b^2}$

where: φ is a conversion coefficient of average skidding distance.

$$\varphi=\frac{\mu(a+b)}{\sqrt{a^2+b^2}}=\frac{\mu(1+\lambda)}{\sqrt{1+\lambda^2}} \qquad (8)$$

where: $\lambda=a/b$

Because of $E=\mu(a+b)/2$, $E^2=\mu^2(a+b)^2/4$

Then

$$4E^2/\mu^2=a^2+b^2+2ab \qquad (9)$$

Because of $E=\frac{1}{2}\varphi\sqrt{a^2+b^2}$, get

$$4E^2/\varphi^2=a^2+b^2 \qquad (10)$$

We can get the landing attraction area from formula (9) and (10):

$$F=ab=2(1/\mu^2-1/\varphi^2)E^2 \qquad (11)$$

Where μ,φ are coefficients which are relative to λ. And are listed in the table 4.

Let:

$$\xi=2(1/\mu^2-1/\varphi^{2)} \qquad (12)$$

then:

$$F=\xi E^2 \tag{13}$$

Table 4. The ratio of length and width and some coefficients

λ	0.2	0.4	0.6	0.8	1.0	1.2	1.5	2.0
μ	0.858	0.790	0.760	0.748	0.745	0.747	0.755	0.772
φ	1.010	1.027	1.043	1.051	1.054	1.052	1.047	1.036
ξ	0.756	1.308	1.624	1.764	1.803	1.777	1.684	1.492

The formula (13) is useful in the field of road network when the construction costs are considerated.

2. This average skidding distance is the shortest as landing collection areas are same and the ratio of length and width in this area is 1. Let area of the Fig.2 equals to A, and the length of one side is X_0, the length of another one is A/X_0, and now

$$E=\frac{1}{2}\sqrt{\left(\frac{2}{3}X_0\right)^2+\left(\frac{A}{3X_0}\right)^2}+\frac{1}{2}\sqrt{\left(\frac{2A}{3X_0}\right)^2+\left(\frac{1}{3}X_0\right)^2}$$

$$\frac{dE}{dX_0}=\frac{1}{2}\times\frac{1}{2}\frac{\frac{8}{9}X_0-\frac{2A^2}{9X_0}}{\sqrt{\left(\frac{2}{3}X_0\right)^2+\left(\frac{A}{3X_0}\right)^2}}+\frac{1}{2}\times\frac{1}{2}\frac{\frac{2}{9}X_0-\frac{8A^2}{9X_0}}{\sqrt{\left(\frac{2A}{3X_0}\right)^2+\left(\frac{1}{3}X_0\right)^2}} \tag{14}$$

let $dE/dX_0=0$, get when $X_0=\sqrt{A}$, i.e., $X_0=\sqrt{A}$, $A/X_0=\sqrt{A}$ $E_{min}=0.745\sqrt{A}$

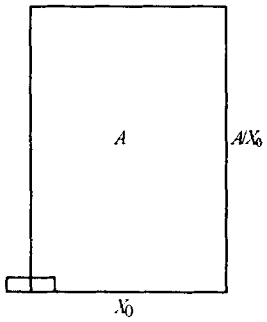

Fig.2. landing collection area

This result can be applied to the logging planning .

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